Faculty of Electrical Engineering

PERFORMANCE OF MULTILEVEL INVERTERS FOR HARMONIC REDUCTION IN DYNAMIC VOLTAGE RESTORER APPLICATION

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A thesis submitted
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DECLARATION

"I declare that this thesis entitles "Performance of Multilevel Inverters for Harmonic Reduction in Dynamic Voltage Restorer Application" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : .....

Name : Norsyuhada Binti Nordin

Date : .....

.....

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality of the award of Master of Science in Electrical Engineering (Industrial Power).

Signature : .....

Supervisor Name : Assoc Prof Ir Dr Rosli Bin Omar

Date :

DEDICATION

This thesis dedicated to my family for all their endless supports.

ABSTRACT

Multilevel inverters are known for their intial usage in high-voltage and high-power applications. This thesis presents the analysis and design of the Three-Phase Cascaded H-Bridge Multilevel Inverters (CHB-MLI) for three and five levels based on Newton-Raphson technique for harmonic reduction in Dynamic Voltage Restorer (DVR) application. The performance of the inverter outputs to reduce harmonics is crucial for DVR applications. Two DC sources were applied for two types of CHB-MLI. These types of inverters used Newton-Raphson method as their controllers. The main aim of this thesis is to design, model, construct, and conduct laboratory testing upon CHB-MLI of a three and five levels prototype for DVR application. The design of suitable multilevel inverters is very important for DVR purposes, so that the AC output voltage waveforms of the inverters have low content of harmonics during energy conversion process from DC to AC of the proposed inverters. The Digital Signal Processing (DSP) TMS320F2812 was used as a tool in order to create the coding based on the Newton-Raphson technique controller. The coding was developed, and then stored into the Digital Signal Processing (DSP) TMS320F2812 for output processing of the waveform of the inverters. The proposed controller using Newton-Raphson technique was applied to both three and five level of CHB-MLI. The optimization of this system has managed to reduce the harmonic contents of the inverters output. The performance of the developed prototype was tested using source codes of the programming for optimization technique. The experimental results of the developed prototype for both three and five levels were monitored and analysed. In addition, the performance of the proposed system was compared between simulation and experimental results for the optimization technique. The simulation and experimental results had shown the effectiveness of the proposed system in reducing harmonic. The waveforms in term of current and voltage were smooth and contain low contents of harmonic. Types of waveforms for five level of CHB-MLI which were more suitable to be used in the DVR applications.

ABSTRAK

Penyongsang berbilang aras terkenal dengan penggunaan awal mereka dalam aplikasi voltan tinggi dan berkuasa tinggi. Tesis ini mempersembahkan analisis dan mereka bentuk Jambatan-H Jujukan Berbilang Aras Litar Penyongsang (JHJ-BALP) tiga fasa untuk tiga dan lima tahap berdasarkan teknik Newton-Raphson untuk pengurangan harmonik dalam aplikasi Pemulih Voltan Dinamik (PVD).Prestasi keluaran penyongsang dalam pengurangan harmonik adalah amat penting dalam aplikasi PVD. Dua sumber bekalan AT digunakan pada dua jenis JHJ-BALP. Semua jenis penyongsang ini menggunakan teknik Newton-Raphson sebagai pengawal. Tujuan utama tesis ini ialah mereka bentuk, model, membina, dan menjalankan ujian makmal ke atas prototaip JHJ-BALP yang telah direka bentuk bagi tiga dan lima tahap untuk aplikasi PVD. Mereka bentuk JHJ-BALP yang sesuai untuk tujuan PVD supaya keluaran voltan AU bagi penyongsang mempunyai kandungan harmonik yang rendah semasa proses penukaran dari Voltan AT ke AU terhadap JHJ-BALP yang dicadangkan. Pemprosesan Isyarat Digital (PID) TMS320F2812 digunakan sebagai alat untuk menjana kod berasaskan kepada pengawal teknik Newton-Raphson. Kod yang dihasilkan kemudiannya disimpan dalam PID TMS320F2812 untuk pemprosesan keluaran gelombang bagi penyongsang. Pengawal yang dicadangkan menggunakan teknik Newton Raphson dibekalkan kepada kedua-dua JHJ-BALP untuk tahap tiga dan lima. Pengoptimuman sistem ini telah dapat mengurangkan kandungan harmonik pada keluaran penyongsang. Prestasi prototaip yang dibangunkan diuji dengan menggunakan kaedah kod program teknik pengoptimuman. Hasil keputusan ujikaji dari prototaip yang direkabentuk untuk tahap tiga dan lima diperhatikan dan dianalisa. Selanjutnya prestasi sistem yang dicadangkan dibandingkan dengan keputusan simulasi dan ujikaji untuk teknik pengoptimuman. Hasil keputusan simulasi dan ujikaji menunjukkan keberkesanan sistem yang dicadangkan dalam mengurangkan harmonik. Bentuk gelombang bagi arus dan voltan adalah berbentuk sinusoidal yang mempunyai kandungan harmonik yang rendah. Jenis gelombang untuk tahap lima bagi JHJ-BALP adalah lebih sesuai digunakan dalam aplikasi PVD .

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
CHB-MLI	-	Cascaded H-Bridge Multilevel Inverter
DC	-	Diode-Clamped
DC	-	Direct Current
DSP	-	Digital Signal Processors
FCs	-	Flying Capacitors
IEC	-	International Electric Code
IGBT	-	Insulated Gate Bipolar Transistor
MI	-	Modulation Index
PWM	-	Pulse Width Modulation
SHE-PWM	-	Selective Harmonic Elimination Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
SVPWM	-	Space Vector Pulse Width Modulation
THD	-	Total Harmonic Distortion

LIST OF SYMBOLS

$f_{carrier}$	-	carrier frequency
$f_{reference}$	-	reference frequency
V_{ref}	-	Voltage Source reference
V_s	-	Voltage Source
f_s	-	Sampling frequency
f_{sw}	-	Switching frequency
l	-	Current, absolute value
f	-	AC power frequency

LIST OF PUBLICATIONS

The following publications have been achieved by this research work:

Journal

1. NorSyuhada, Rosli Omar, Mohammed Rasheed, Afiqah Sabari. "Optimization of a Three Phase Cascaded H-bridge Multilevel Inverter for Harmonic Elimination Based on Newton- Raphson" Journal: Australian Journal of Basic and Applied Sciences ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6569-6580.
2. Rosli Omar, NorSyuhada, Mohammed Rasheed, Marizan Sulaiman, Krismadinata and Afiqah Sabari "Comparison Performance of Multilevel Inverters for Harmonic Reduction in Dynamic Voltage Restorer (DVR) Application" World Applied Sciences Journal (WASJ) : Accepted.

Conference

1. NS Nordin, Rosli Omar, M Sulaiman, MFM Elias, "Comparative Study of Cascaded H-bridge Multilevel Inverter Model Based on Power Electronic Simulator (PSIM)" IEEE Conference Publications, Clean Energy and Technology (CEAT) 2014, 3rd IET International Conference on Date 24-26 Nov. 2014.
2. NorSyuhada Nordin, Rosli Omar, Krismadinata, Mohammed Rasheed, Afiqah Sabari, "Harmonic Minimization of a Three Phase Cascaded H-